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CONTROL OF EXCESSIVE EMISSIONS AND FUEL CONSUMPTION BY
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Control of Excessive Emissions and Fuel Consumption by In-Use Motor Vehicles

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Air Pollution Control Directorate
August 1981

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CONTROL OF EXCESSIVE EMISSIONS AND FUEL CONSUMPTION BY IN-USE MOTOR VEHICLES

Mobile Sources Division
Engineering Assessment Branch
Air Pollution Control Directorate

in consultation with the

Technical Advisory Committee
On In-use Motor Vehicle Emissions

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ABSTRACT

Ten years of collaborative federal-provincial research have revealed that although new cars are capable of meeting emission standards, with excellent fuel consumption, generally poor maintenance of the engines of Canadian vehicles causes both emissions and fuel consumption to be excessive. This research was summarized in a discussion paper by Environment Canada engineers. From September 1979 to January 1981, a Technical Advisory Committee, with representatives from industry, government and the general public, reviewed the discussion paper and made recommendations. This report, resulting from that review, provides the background, including a test procedure, for a national guideline on in-use motor vehicles. A mandatory inspection program by local governments is proposed as the most cost-effective solution to the dual problem of excessive emissions and fuel consumption.

RÉSUMÉ

Dix années de recherche coopérative fédérale-provinciale ont révélé que les nouvelles voitures peuvent être conformes aux normes antipollution et avoir une excellente cote de consommation d'essence, mais le mauvais entretien des moteurs de ces voitures au Canada réduit considérablement ces avantages. Les résultats de ces recherches sont résumés dans un document de travail préparé par des ingénieurs d'Environnement Canada. De septembre 1979 à janvier 1981, un comité consultatif technique, formé de représentants de l'industrie, du gouvernement et du grand public, a examiné ce document et fait des recommandations. Le présent rapport, qui découle de cet examen, fournit les données fondamentales, y compris une méthode d'essai, en vue de l'élaboration d'une ligne directrice nationale concernant les véhicules automobiles en usage. Le rapport précise que la réalisation d'un programme d'inspection obligatoire par les gouvernements locaux serait la solution la plus rentable au double problème des émissions excessives et de la surconsommation d'essence.

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EXECUTIVE SUMMARY

1. In Canada, transportation is responsible for 40% of total air pollution. The majority is generated by gasoline-powered motor vehicles. Furthermore, the largest part of this pollution is emitted in urban areas where the bulk of the population lives.

2. The federal government has had mandatory emission standards for new motor vehicles since 1971 and the manufacturers have responded by producing vehicles that meet these standards. Unfortunately, once in consumers' hands these automobiles are generally poorly maintained, resulting in excessive emission rates as well as excessive fuel consumption.

3. A Technical Advisory Committee, consisting of representatives of federal and provincial agencies as well as industry and consumer groups, was convened in October 1979 to review current research data and the elements of a proposed inspection program and thus to develop the most effective method of minimizing excessive emissions and fuel consumption in Canada.

4. The research to date has indicated that:

   a) in-use vehicles are poorly tuned with respect to emissions;
   b) excessive emissions and fuel consumption is mostly (85% of failing vehicles) due to carburetor maladjustment;
   c) in the absence of maladjustments emissions increase only slightly with age;
   d) vehicle use is greater for newer vehicles;
   e) new vehicles are generally serviced by dealerships who apparently are to blame for most of the initial maladjustment; (since dealership mechanics have good training opportunities available to them, it would appear that the maladjustments noted in (b) are not the result of a lack of training.)
   f) by tuning in-use vehicles for optimized emissions, driveability is <u>not</u> impaired and fuel consumption is improved.

5. Following from those research results the dual problem of excessive emissions and fuel consumption can be attacked most effectively by implementing a motor vehicle emission inspection program <u>in specific metropolitan areas</u> while exempting areas with low population densities. In contrast with certain existing programs which

attempt to relate directly to new vehicle emission standards, this program should have the simpler goal of holding each vehicle very close to its design specification.

Furthermore, the recommended program would:

a) inspect vehicles annually, beginning at first registration;
b) ensure enforcement preferably by the registration process;
c) be carried out in government-controlled inspection stations (but which might be contractor-operated);
d) have a test procedure that can be easily done by the service industry and that concentrates on correct carburetor adjustment;
e) have pass/fail standards that optimize both emissions and fuel consumption without sacrificing driveability;
f) be "phased in", one model year at a time, beginning with the then-current model year (although for the fastest fuel consumption impact the program should include older cars, at least on a voluntary basis) to ensure the smoothest possible introduction in terms of both testing operations and the social acceptability of the program.

6. The recommended test procedure is a Hi-Lo idle test which measures hydrocarbon (HC) and carbon monoxide (CO) at 2500 rpm and at idle with the transmission in park or neutral. The emission limits related to this test procedure should be vehicle-specific and based on the CO (HC optional) emissions from a vehicle in a good state of repair with some allowance for age deterioration.

7. Should a particular agency consider that an emission inspection program might be desirable in an urban centre, the following factors, in addition to the severity of the air pollution or fuel consumption situation, should be investigated:

a) the market penetration and effectiveness of "tamper-proof" engine controls on vehicles;
b) the cost effectiveness of a program in the metropolitan areas under their jurisdiction;
c) the acceptability (public and political) of such a vehicle inspection program;
d) the relationship between departments controlling safety, energy and emission programs;
e) the possibility of incorporating a safety inspection program (or with an existing one) without loss of program effectiveness.

GLOSSARY OF TERMS

CANADIAN NEW VEHICLE EXHAUST EMISSION STANDARDS

	Hydrocarbons (grams/mile)	Carbon Monoxide (grams/mile)	Oxides of Nitrogen (grams/mile)
1971	3.4	39.0	
1973	3.4	39.0	3.0
1975*	2.0	25.0	3.1

* test procedure changed; standards in effect until 1983.

HC	-	hydrocarbons
CO	-	carbon monoxide
NO_x	-	oxides of nitrogen
I/M	-	inspection - maintenance
TAC	-	Technical Advisory Committee
EPA	-	Environmental Protection Agency (of the United States)
rpm	-	(engine) revolutions per minute
FTP	-	Federal Test Procedure - this is used in determining mass exhaust emissions (grams/mile) for HC, CO and NO_x
L	-	litre
km	-	kilometre
MVMA	-	Motor Vehicle Manufacturers Association
ppm	-	parts per million

1 INTRODUCTION

The federal inventory of air contaminant emissions (1)* shows that transportation is responsible for 40% of Canada's total air pollution burden on a mass basis. More specifically, 40% of all hydrocarbon (HC) emissions, 54% of all oxides of nitrogen (NO_x) emissions and 57% of all carbon monoxide (CO) emissions are from transportation sources. Of these transportation-caused emissions, more than 75% are generated by gasoline-powered motor vehicles and about one half of these vehicles are registered in only 12 major cities in Canada: Montreal, Toronto, Vancouver, Ottawa, Quebec, Winnipeg, Hamilton, Edmonton, Calgary, Kingston, Regina, and Saskatoon.

Furthermore, various vehicle-use surveys have shown that 50% of the total vehicle-miles (kilometres) travelled in Canada are accumulated in urban centres and also that 83% of intercity travel and 97% of urban travel is by automobile. Automobiles then, as well as being responsible for a large percentage of the total tonnage of air pollution in Canada, could well be responsible for over 60% of the air contaminants actually inhaled by Canadians.

Federally mandated emission standards for new motor vehicles have been in effect in Canada since 1971. Unfortunately, these HC, CO and NO_x standards have not been as effective as expected, due mainly to poor maintenance of vehicles in consumers' hands. It is theorized that this poor maintenance, mostly maladjustment, both accidental and deliberate (tampering), is a holdover from the early days of emission control. At that time both driveability and fuel consumption (about 8% on average) were sacrificed for emission control at minimum cost and the service industry generally responded to customer pressure for a "smooth running" car by enriching the idle fuel mixture. While technology has taken care of the practical problems, the societal problem behind this tampering and maladjustment persists.

In the United States (2) the Environmental Protection Agency has determined that emission reductions resulting from implementation of vehicle emission inspection/maintenance (I/M) programs can make an important contribution towards meeting National Ambient Air Quality Standards.

In October 1979, the Mobile Sources Division of the Air Pollution Control Directorate, Environment Canada, convened a Technical Advisory Committee (TAC). The

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* Numbers in parenthesis refer to references listed at the end of this report.

TAC's terms of reference were to review a draft report containing current information and existing abatement procedures relative to excessive emissions and fuel consumption by in-use vehicles, to bring forth pertinent new information and to make recommendations for modifications to the draft abatement procedures. The TAC consisted of representatives of several federal departments, provincial Environment and Transport departments, automobile manufacturing and service industries and the Canadian Automobile Association (CAA) (Appendix D).

The purpose of this report is to present the relevant background information, to discuss the ideas brought forward by the TAC and to serve as the main reference for a national guideline on in-use motor vehicle emission control. Subsequently, this guideline can be adopted and implemented by those provinces (or municipalities) in areas or urban centres where excessive emissions and fuel consumption by motor vehicles are considered a problem.

2 CONTROL OF VEHICLE DESIGN

In the United States the federal motor vehicle emission control program is composed of three primary elements:

1. Certification Program - supervised certification of prototype vehicles to show that the design will meet federal emission standards.
2. Selective Enforcement Auditing - end-of-assembly-line testing to assure that production vehicles meet standards when new.
3. Surveillance and Recall - the U.S. Clean Air Act contains the requirement that manufacturers recall vehicle types found, through in-use surveillance, to fail standards because of design defects.

In Canada, the manufacturers do their own 'self-certification' testing and the Departments of Transport and Environment carry out a compliance audit of production vehicles. Vehicles are purchased from dealerships and then tested (3) in a fashion identical to EPA procedures but for compliance with the Canadian federal emission standards.

The objective of both Canadian and U.S. programs is to provide consumers with motor vehicles that can meet emission standards when they are properly maintained and operated. Unfortunately, even with these federal enforcement programs, many in-use

vehicles are not being operated at their design levels because of disabling of control systems, incorrect adjustments and other poor maintenance practices.

3 EMISSION CAPABILITIES OF NEW VEHICLES (4)

During the initial stages of the Canadian compliance testing program, the practice was to drive 4000 miles (3) with the vehicle in the condition it was received from the dealer. Many of these vehicles had excessive emission levels at the first 4000-mile test, but when adjusted to the proper settings (manufacturers' specifications) substantial improvements were observed. The single most common problem was that of maladjusted idle mixture.

This experience, together with subsequent compliance testing, has led to the conclusion that the manufacturers are producing automobiles that can meet the emission regulations when adjusted to manufacturers' specifications. In fact, based on five years of testing as shown in Figure 1, the emission performance of new cars (on average) is consistently 20 to 30% better than the regulated standards.

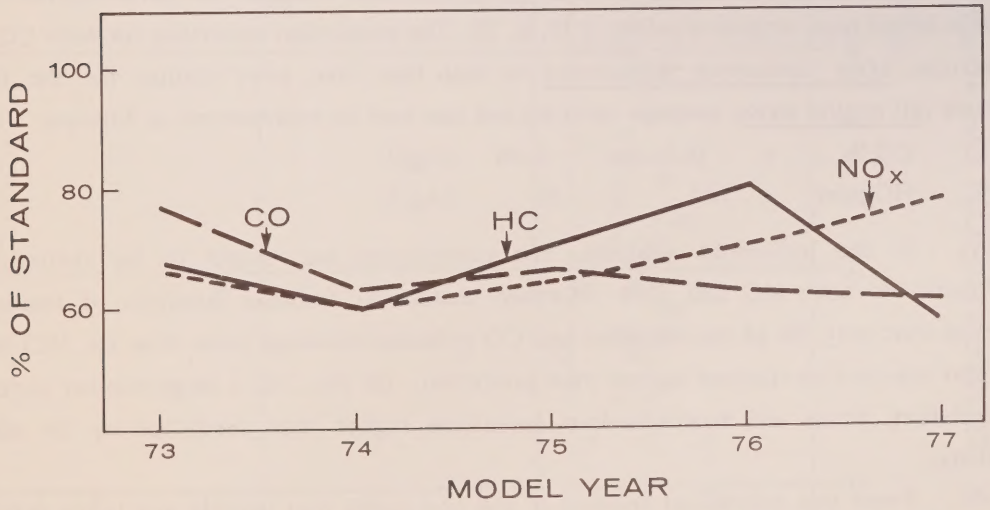

FIGURE 1 MODEL YEAR EMISSION TRENDS FOR NEW VEHICLES

4 EMISSION PERFORMANCE OF IN-USE VEHICLES

The good emission performance (capability) of new cars is largely being lost in the in-use fleet because of poor maintenance or tampering, or both. A number of programs have been conducted over the past seven years to determine the emission condition of the Canadian fleet. In those programs conducted in the field the main surrogate for emission condition was a Hi-Lo idle emission test - HC and CO at 2500 rpm and at idle. (These steady state tests are also being routinely used in the federal compliance program at the end of each compliance test as diagnostic aids.)

The general relationship between the major maladjustment factor (idle mixture) and actual mass emissions (grams/mile) has been one of poor correlation at the lower CO and HC levels, as shown in Figures 2 through 5 (data provided by General Motors on several different vehicles). As will be noted from the X-axis scale, only the very lowest range of values for CO and HC was explored in these tests by General Motors (0 to 0.3% and 0 to 100 ppm respectively). However, as the idle %CO is increased (mixture is made richer) to the actual range of values found in field testing, there is a proportional increase in CO emissions which can vary significantly from vehicle to vehicle as shown in Figure 6.

Analysis of variance on three in-use programs (Alberta, Nova Scotia, Manitoba) was conducted on the variables (predictors) thought to have relevance to emission levels (age, engine size, etc.) (5, 6, 7). The prediction equations for both CO and HC at idle, after carburetor adjustment to lean best idle, were similar for the three programs (all engine sizes, average vehicle) and can best be represented as follows:

$$\text{CO \%} = 0.6 + 0.08\ (\text{Age})$$

$$\text{HC ppm} = 185 + 20\ (\text{Age})$$

In the individual analyses, the correlation was found to be statistically significant for both HC and CO. Further statistical analysis (analysis of residuals) indicated that only 5% of the vehicles had CO emission readings (also true for HC) more than two standard deviations higher than predicted. Of this 5%, a large number actually had emissions three and four standard deviations higher than predicted by the above equations.

From this statistical analysis it was concluded that vehicle age is the primary characteristic to use in estimating readily attainable pollutant concentrations in the exhaust and that, for further refinement, engine size (no. of cylinders) should be taken into account.

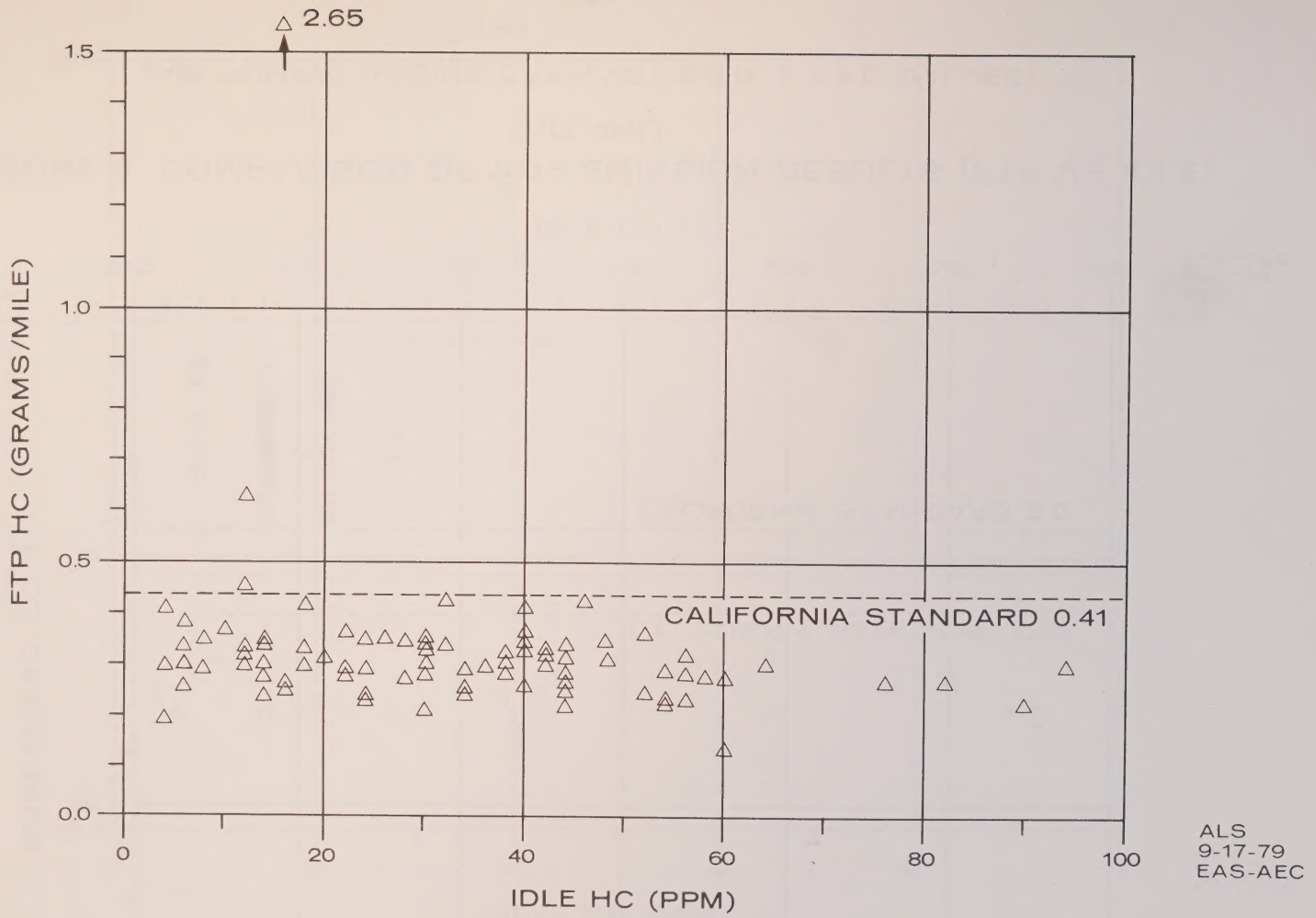

FIGURE 2 COMPARISON OF 1979 EMISSION RESULTS (FTP VS IDLE)
910L4RU

(AIR PUMP/OXIDIZING CATALYST / E.G.R. & E.F.E. VALVES)

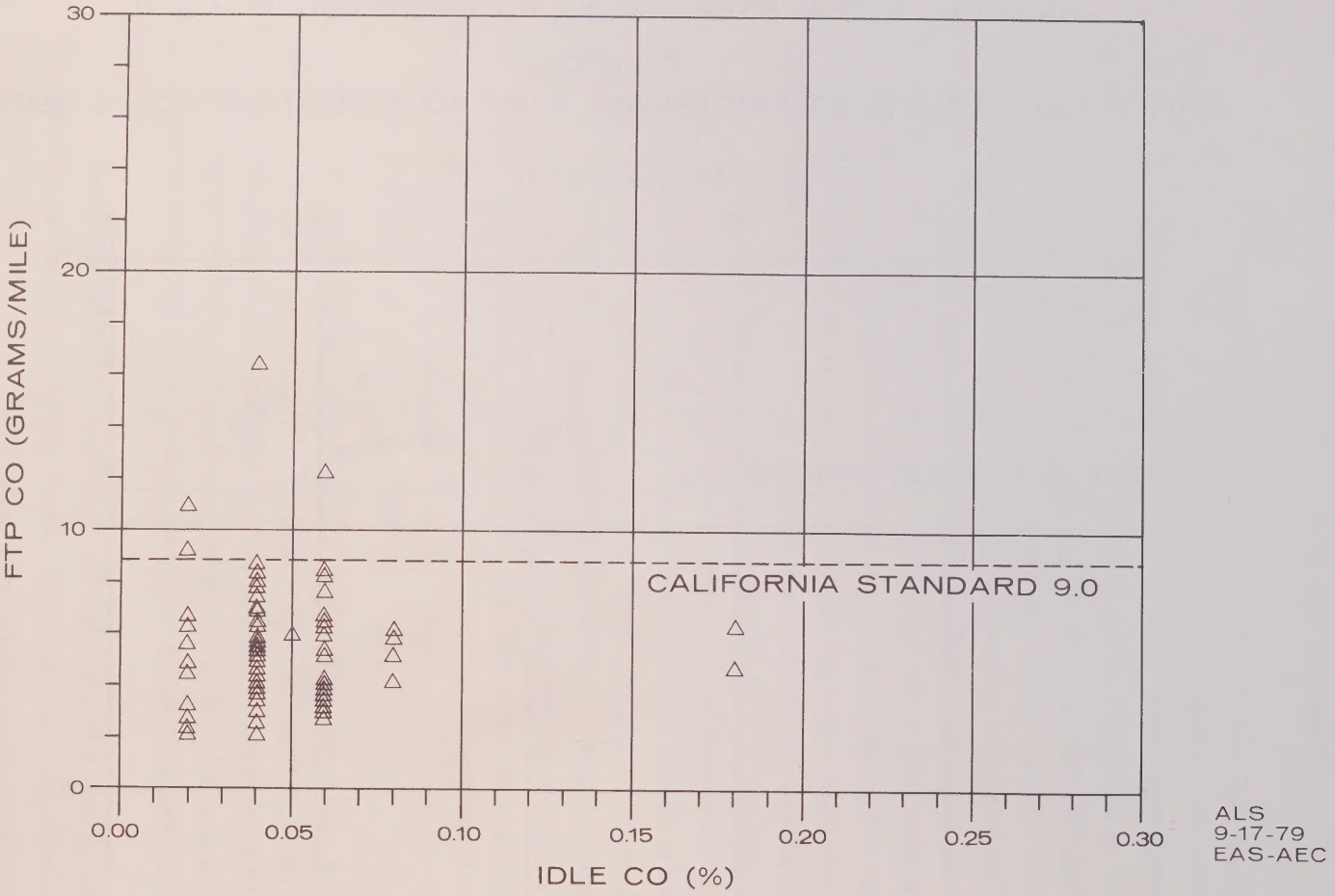

FIGURE 3 COMPARISON OF 1979 EMISSION RESULTS (FTP VS IDLE)
910L4RU

(AIR PUMP/OXIDIZING CATALYST/E.G.R. & E.F.E. VALVES)

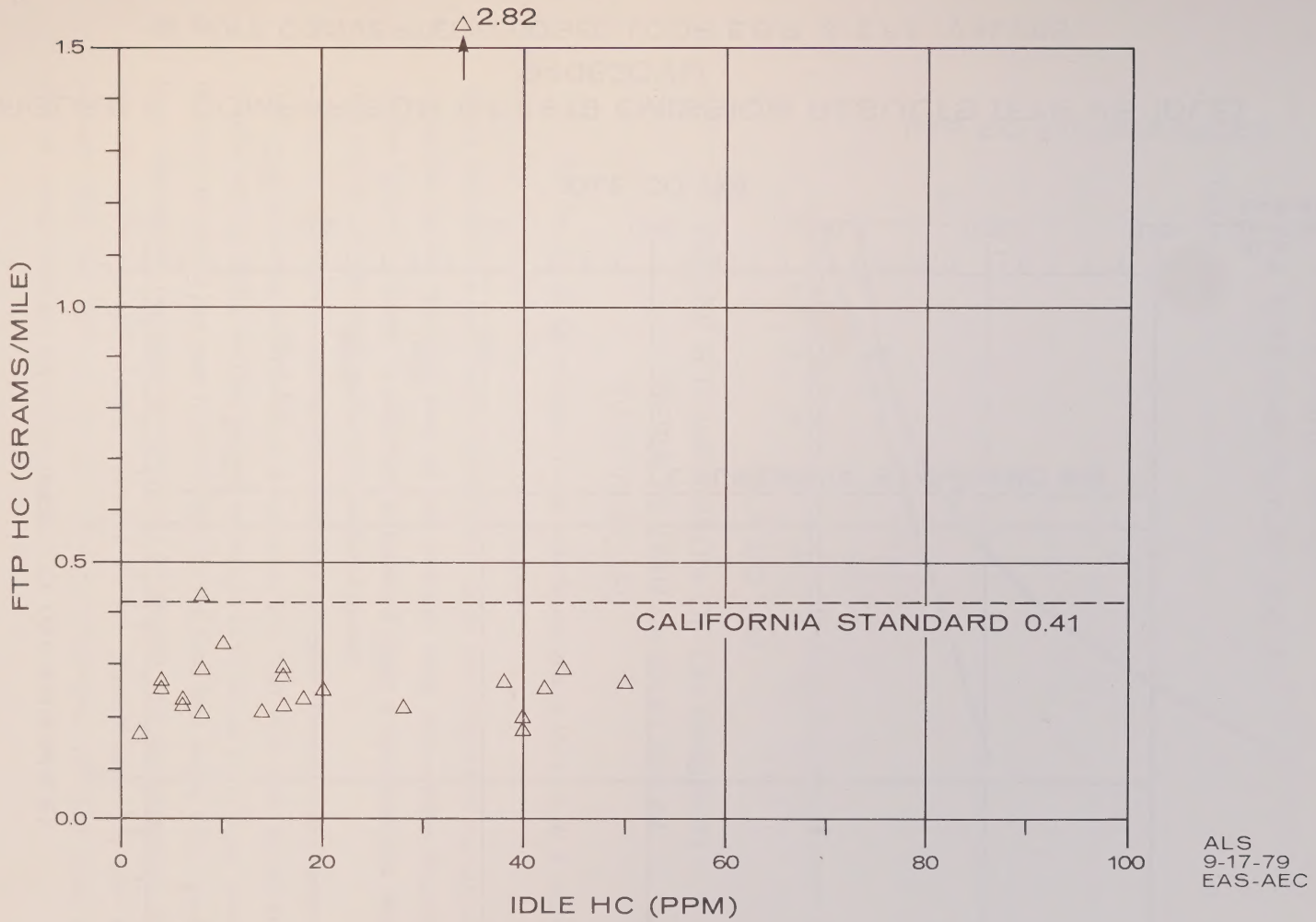

FIGURE 4 COMPARISON OF 1979 EMISSION RESULTS (FTP VS IDLE)
940E2CYU

(3-WAY CONVERTER/CLOSED LOOP E.G.R. & E.F.E. VALVES)

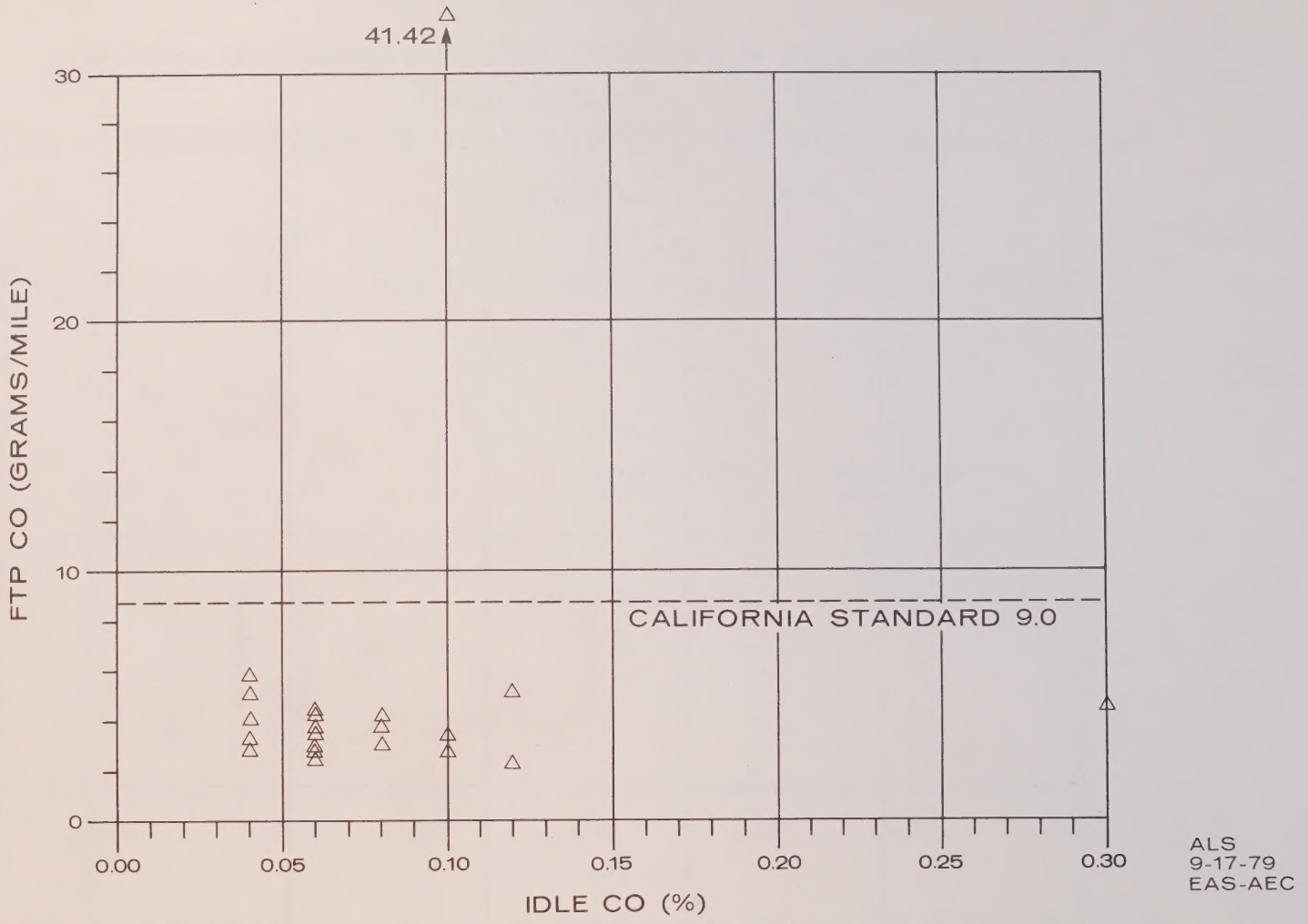

FIGURE 5 COMPARISON OF 1979 EMISSION RESULTS (FTP VS IDLE)
940E2CYU
(3 WAY CONVERTER/CLOSED LOOP E.G.R. & E.F.E. VALVES)

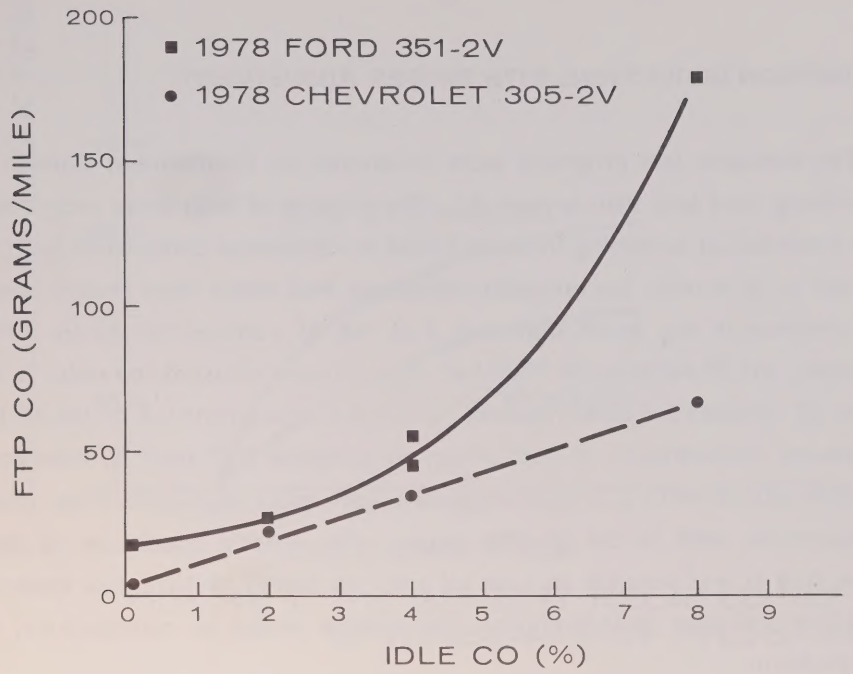

FIGURE 6 COMPARISON OF CO EMISSION RESULTS (FTP vs IDLE) FROM TWO VEHICLES

The results of the various in-use vehicle programs (5, 6, 7, 8, 9, 10) conducted in the past lead to the following general conclusions:

a. In-use vehicles are very poorly tuned particularly with respect to the idle mixture;

b. Sometime during the first year of use, average mass and volume emission performance (grams/mile and % pollutant in exhaust) make a step-function deterioration that can be attributed to carburetor maladjustment;

c. Emissions deteriorate only slightly with age (or use). Vehicle manufacturers report that mass emission deterioration is normally less that 20% over 80 000 km. In-use vehicle testing indicates that volume emissions deteriorate by 13% per year;

d. Distance travelled per year remains high for the first four years, then tapers off;

e. New vehicles are normally serviced only by dealers who are apparently responsible for the initial maladjustment observed in b. (End-of-assembly-line tests (11) indicate that over 97% of vehicles meet specifications, yet field tests show that 50% of 1-year-old cars are maladjusted).

5 EMISSION REDUCTIONS WITH PROPER ADJUSTMENT

Two emission test programs were conducted by Environment Canada in 1977 and 1979 involving cars less than a year old. The purpose of both these programs was to evaluate the potential of screening in-use vehicles to determine compliance with new-car regulations and to determine the emission reductions that result from proper adjustment. In the 1977 program it was found that only 5 of the 41 vehicles tested (or 12%) were properly adjusted and 30 vehicles (or 73%) had idle mixtures adjusted too rich. In the 1979 program 42 of 67 vehicles (or 63%) required carburetor adjustment (14 of the 67 had non-adjustable, 'sealed' carburetors). In both programs complete FTP tests (3) were conducted before and after adjustment. CO mass emissions were reduced 35-55% after adjustment while HC reductions were in the 10-30% range. The general conclusion of these two programs was that it was possible to tune all vehicles tested to have low emissions and good driveability and that maladjustment, not vehicle design or manufacture, was the cause of the problem.

Figures 7 and 8 (12) show the air pollution reduction potential of I/M and the emission levels of vehicles passing and failing an existing I/M program in Portland, Oregon. In Figure 7, the stringency factor relates to the percentage of the population that fail a particular standard or cut point. For example, if it was found that 30 of 100 vehicles had emission levels above 3% CO, then a 3% CO standard would have a 30% stringency factor. This stringency factor is frequently used in the United States for setting politically acceptable pass/fail levels usually in the 20 to 35% range. It is noteworthy that this leaves the bulk of the maltuned vehicles untouched by the I/M program.

6 EFFECT OF EMISSION-ORIENTED MAINTENANCE ON FUEL ECONOMY/CONSUMPTION

6.1 Parameters Affecting Fuel Consumption

As a vehicle is operated over a duty cycle there are many things that govern the power that must be generated in order for the vehicle to complete the cycle. Some of these parameters are not greatly alterable when in consumers' hands as they are related to either road and weather conditions or to the design and manufacture of the vehicle. Therefore the effect they have on fuel consumption over a cycle is fixed for that

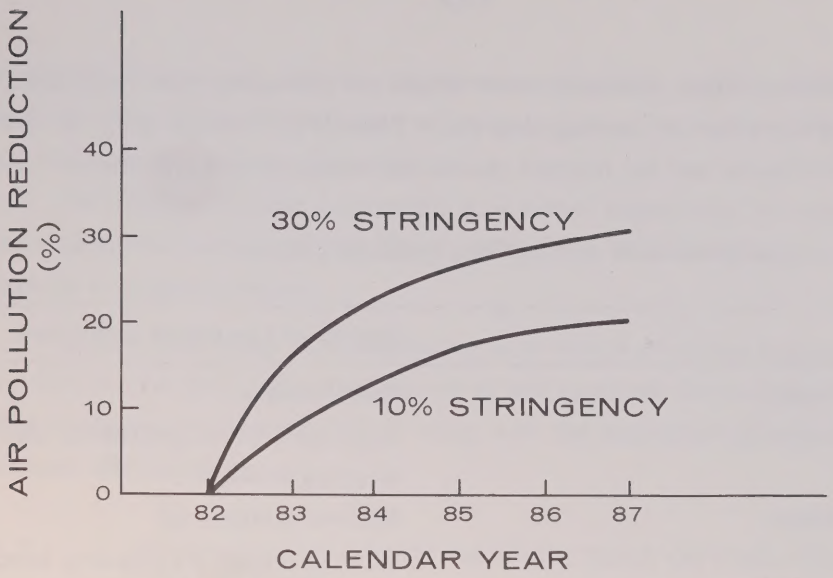

FIGURE 7 I/M BENEFIT RELATED TO STRINGENCY OF PROGRAM

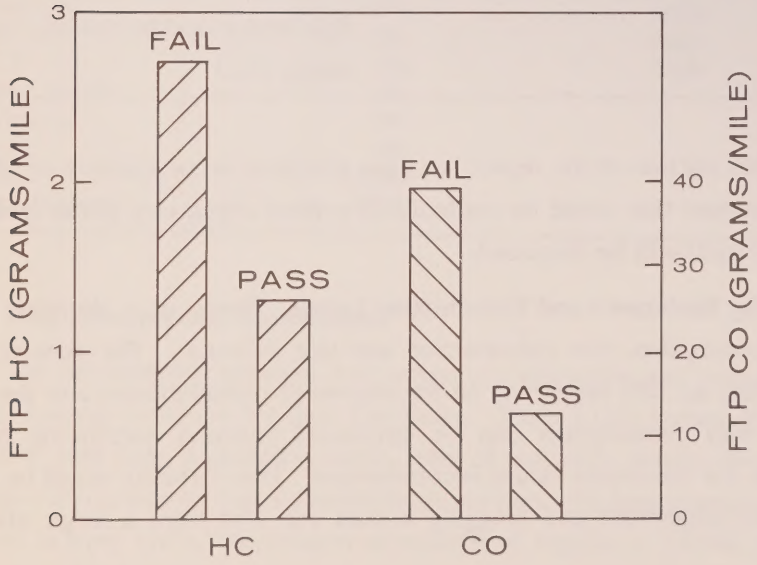

FIGURE 8 FTP EMISSION LEVELS OF CARS PASSING AND FAILING THE OREGON INSPECTION TEST (1975-77 MODELS)

particular vehicle. Other elements, over which the consumer does have some control, affect fuel consumption to varying degrees. Table 1 (13) shows some of the factors affecting fuel economy and the relative control the consumer has over them.

TABLE 1 PARAMETERS AFFECTING FUEL ECONOMY

Parameters	Degree of Control by Consumer
Aerodynamic drag	None (design)
Rolling resistance	Significant (tires, pressures, alignment dragging brakes)
Transmitting losses	Minimal (lubricants)
Accessories	Minimal (lights, alternators, fans, etc.)
Engine efficiency	Significant (state of tune)
Vehicle weight	None (design)
Fuel composition	None (refinery)
Driving habits	Significant
Traffic and road conditions	None
Ambient conditions	None
Loading	Significant (trailer towing, carrying cargo, etc.)

As this section of the report has been prepared in the context of I/M programs, only those parameters that could be controlled by some regulatory group (rather than by the consumer himself) will be discussed.

6.1.1 Rolling Resistance and Transmitting Losses. There is a definite relationship between fuel consumption, tire construction and tire inflation. The penalty in fuel use (14) can be as high as 20% depending on the degree of underinflation and the duty cycle. In this regard fuel consumption can be optimized (without sacrificing handling) by inflating tires to the maximum values recommended. This normally would be in the 28-32 psi range. Wheel alignment and dragging brakes can also have a large effect on fuel economy.

Transmitting losses (losses occurring in transferring power from the engine to the rear wheels) are to a large degree a function of gear design, transmission type and

bearing design. There can, however, be some improvements made in fuel consumption by the use of the new "slippery" lubricants which are claimed to reduce friction and stabilize viscosity over a large temperature range.

For control purposes, however, it is rather impractical to consider regulation of either rolling resistance or transmitting losses. This leaves only engine efficiency as a candidate for regulatory control.

6.1.2 Engine Efficiency. The efficiency with which an engine operates is dependent on many factors that are within the control of the consumer (knowingly or unknowingly). A number of these are listed in Table 2 along with the estimated penalty in fuel economy and resultant idle emissions.

TABLE 2 ESTIMATED EFFECT OF MALFUNCTIONS ON FUEL ECONOMY AND EMISSIONS

Fault	Estimated Fuel Economy Penalty	Idle Emissions	
		CO	HC
Misfire	6 - 15%	-	High
Rich Carburetion	10 - 13%	High	High
Rich Idle Mixture	2 - 13%	High	High
Rich Choke	2 - 5%	High	High
Plugged PCV	3 - 5%	High	High
Incorrect Idle Speed	0 - 4%	-	High
Incorrect Timing	0 - 7%	-	High
Vacuum Leak	0 - 1%	-	High
Poor Ignition	1 - 13%	-	High
Faulty Rings, Valves	0 - 10%	-	High

6.2 Fuel Economy and Maintenance

The relationship between fuel economy, emissions and maintenance has been the subject of many studies in the last few years. Table 3 (15) breaks down these studies into inspection test type, pass/fail criteria, level of mechanic ability concerning emissions and the effect of repairs on fuel economy/consumption. As fuel economy/consumption is a function of driving cycle, the column on benefit of repairs is further broken down into four segments of which the first three (urban, highway, combined) are the federal laboratory test procedures conducted on a dynamometer, and the last (other) column includes test-specific cycles and actual consumer driving.

TABLE 3 SUMMARY OF STUDIES ON FUEL ECONOMY BENEFIT DUE TO INSPECTION AND MAINTENANCE

Study	Sample	Test Type Pass/Fail Criteria		Level of Mechanic	Mpg or L/100 km	Repaired Vehicle Fuel Economy Benefit			
						Urban	Highway	Combined	Other
1. Impact of Diagnostic Inspection on Automobile Fuel Economy and Emissions Bayler & Eder SAE 780028 N.H.T.S.A.	26 31 322	Idle Loaded & idle 4 state	20% fail 20% fail	High High Average	mpg mpg mpg 4.7%	(6.7%) (8.4%)	2.7% 1.6%	4.9% 5.3%	 (reported by owners)
2. Fuel Economy Improvements through I/M Exxon R. & Eng. Co. SAE 760003	105 unknown	Idle Idle	50% fail (varying fail rate)	High Average	mpg mpg			13.0% 8 to 14%	
3. In-Use Performance of 75/76 Vehicles Rest. Main Program Status Report EPA Nov. 15, 1977	300	Idle	25% fail	High	mpg			2.0%	
4. I/M Analysis of EPA's RM 76 Program	97	Idle	30% fail	High	mpg			3.9%	
5. I/M Analysis of EPA's RM 76 Program	11	Idle	25% fail	High	mpg			4.0%	
6. EPA Analysis of California data (1977)	31	Idle	20% fail	High	mpg			1.8%	
7. EPA Analysis of Riverside I/M Program (1974)	349	Idle	35% fail	Average	mpg	3.1%			
8. Champion International Tune-up survey 4 year study 1978	310 (U.S. & Can) 74 (Eur) 20 (Mex)	Idle Idle Idle	30% fail CO% 4.5 HC ppm 400 30% fail	High	mpg				11.4% (variable 11.1% speed cycle) 26.4%

TABLE 3 SUMMARY OF STUDIES ON FUEL ECONOMY BENEFIT DUE TO INSPECTION AND MAINTENANCE (cont'd)

Study	Sample	Test Type Pass/Fail Criteria		Level of Mechanic	Mpg or L/100 km	Repaired Vehicle Fuel Economy Benefit			
						Urban	Highway	Combined	Other
9. Portland Study Interim Analysis EPA January 1979	200	Idle	30% fail	Average	mpg	0.7%	-1.0%	0%	
10. Effects of I/M Programs-Fuel Economy, EPA, March 1979. GM tests on 1981 + Prototypes	Review of Programs	65% idle 35% loaded	various	Average to High		5%	1 to 2%	3-4%	
	1000+								
	7			High				9-30%	
11. Evaluation of the Effectiveness of Auto Engine Adjustments to Reduce Emissions C.A.R.B. (contract) June 22, 1973	300	Idle	20% fail	High	g/test	4.9%			
12. Evaluation of Restorative Maintenance and Catalyst Replacement on Exhaust Emission on 8 High-Mileage Cars EPA, June 1979	8	Idle	man spec.	High	mpg			3.2%	
13. Communications with EPA memo, Dec. 12, 1979	31	Idle	3% CO	High	mpg	3%	1%	2%	
	23	Idle	3-5% CO	High	mpg	5%	3%	4%	
	31	Idle	5% > up	High	mpg	7%	1%	4%	
14. Regulated and Unregulated Exhaust Emissions from Malfunctioning Automobiles. Urban & Garbe SAE 790696 Southwest Research & EPA	5			High	L/100 km	9.6%			

TABLE 3 SUMMARY OF STUDIES ON FUEL ECONOMY BENEFIT DUE TO INSPECTION AND MAINTENANCE (cont'd)

Study	Sample	Test Type Pass/Fail Criteria		Level of Mechanic	Mpg or L/100 km	Repaired Vehicle Fuel Economy Benefit			
						Urban	Highway	Combined	Other
15. Operation Tune-up. EMR and CAA 1978-79	12 Barrie 12 Montmagny 13 Ottawa	Tune to spec. & driver training		High	mpg			12.9% 15.9%	 24.5%
16. Auto-Efficiency Test Program, Centre for Energy Studies, Nova Scotia 1979	25 46	Idle Idle	Man spec. Man spec.	High	mpg				16.6% (city route) 15.8% (reported)
17. Unpublished data, Environment Canada, Mobile Sources Div. Oct., Dec. 1977	41 (1977 models only)	Idle	Man spec.	High	mpg	8.0%			
18. Unpublished data, Environment Canada, Mobile Sources Div. June 1979	67 (1979 models only)	Idle	Man spec.	High	mpg	5.2%			
19. Unpublished data, Environment Canada, Mobile Sources Div. Dec. '79 - Jan. '80	21	Idle	Man spec.	High	L/100 km	6.6%	0.7%	4.5%	
20. Reducing Fuel Consumption and Emissions by an Optimizing Tune-up MVEDD IV 1975 Dr. Oberdorfer	14	Idle Diagnostic	Man spec.	High	mpg				11.4% (fixed city route)
SUMMARY	all			Average & High		3.9% (1125)*		0.2%(363)	3.5% (915)
	Excluding average level mechanic group (studies 7 and 9)			High		5.5% (576)	1.8% (163)	4.4% (715)	

* Numbers in brackets refer to sample size

The urban fuel economy benefits vary from a low of 0.7% to a high of 9.6% and averages 3.9%. This includes two programs where the mechanic level was average, that is, the mechanics were not emission oriented. With these excluded, the average benefit increases to 5.5%. The highway fuel economy benefits vary from -1% to +3% and average 0.2%, but with the average mechanic level group removed, this increases to 1.8%.

The combined fuel economy benefits vary from 0% to 13% with an average of 3.5%. With the average level mechanic group removed, this average is 4.4%.

It is difficult to assess on a comparative basis the studies whose results appear in the "other" column, without first reviewing the objective of the program and the test procedures used. For example, the data from Operation Tune-Up (Study 15) reflected the benefits of tune-up as well as changes in driver habits. The objective of this program was such that individual quantification was not required. Other programs involved tuning vehicles and having individual owners report the perceived improvement in fuel consumption. While these programs do show highly positive results, the number of uncontrolled variables does not permit use of the results for predicting the fuel-saving potential of proper maintenance.

The program in Portland, Oregon (Study 9) is showing virtually no fuel economy improvement after maintenance has been conducted. This has been attributed (16) to Portland's relatively untrained (from an emission standpoint) mechanics not setting vehicles to manufacturers' specifications. While it appears that idle mixture is being properly set, preliminary analysis indicates improper spark retard occurring on a number of the vehicles causing a fuel economy loss which offsets the fuel economy benefit shown by other studies. This is being referred to in the Portland area as the "lean 'n' late" adjustment that will make any car "pass inspection" (17).

The results of Study 10 (Effects of the I/M Program on Fuel Economy) have not been included in the summary number since it (Study 10) includes a number of studies that were also used in this analysis (including the Portland Study (9)). It was reported in that study that a 3-4% improvement in combined fuel economy could be obtained by performing restorative maintenance to manufacturers' specifications, which is very similar to the summary of results found in Table 3.

The testing that was conducted by Environment Canada (Study 19) had a combined fuel economy benefit of 4.5%, very close to the 4.4% seen in the summary in Table 3. This particular program studied the effect on fuel economy of adjusting a group of 1970 to 1979 model year vehicles to manufacturers' specifications.

6.3 Fuel-Saving Potential

Proper maintenance (where required) can improve the average fuel economy of the fleet of repaired vehicles by:

5.5% in urban driving conditions;
1.8% in highway driving;
4.4% in combined conditions.

Surveys conducted in Canada show that some 70-75% of vehicles are not adjusted to manufacturers' specifications (largely carburetor maladjustments). If one were to use a 70% capture ratio standard, then a total fleet fuel saving of over 3% could be realized. It should be noted that this figure is based on laboratory tests and does not include larger savings obtained in field test programs conducted by such competent organizations as N.H.T.S.A., Champion and others; the 3% benefit must then be considered conservative. There is a good probability that a well managed I/M program, incorporating some checks specific to fuel consumption (e.g., tire pressure), could yield a larger improvement in fleet fuel consumption.

7 IMPLEMENTATION OF EMISSION I/M

The implementation of I/M involves the consideration of several factors. These include the fleet to be inspected, the frequency of inspection, the enforcement of the standards and who does the inspection.

At this point it should be formally acknowledged that the Canadian research on I/M programs generally, and implementation in particular, has been greatly assisted by our colleagues in the U.S. EPA who have willingly provided information about their programs. Appendix A is an excerpt from an EPA document (2) that outlines the legal authority, public relations and consumer protection involved in the implementation of an I/M program. While this has been prepared in the U.S. context, much of it is also applicable in Canada.

7.1 Target Fleet

The inspection programs conducted to date have shown that by the time vehicles are one year old, more than 50% have been maladjusted (deliberately or otherwise) from an emission standpoint (mainly carburetor). Since these new vehicles are

under warranty for at least a year, and are likely being serviced by the dealer network until they are three years old, it would appear that the dealerships are responsible for the initial maladjustments that are taking place. If, initially, only the current model year vehicles were involved in an I/M program, the maladjusted 50% could be reduced to the 1 or 2% that have some kind of mechanical problems other than simple carburetor adjustments. If an I/M program had a phased build-up by model year, the entire program could be implemented in an incremental manner thereby reducing both start-up problems and the initial capital and manpower investments.

Furthermore, the shock to the service industry would be much less than if I/M were imposed on all of the vehicle fleet at one time and would provide the non-dealer segment of the service industry an appropriate lag time to prepare for the emission tuning of vehicles, and to become more familiar with the various control systems being introduced. This presumes, of course, that the dealers already have the knowledge and ability to work with emission controls based on information gained by attending manufacturers' courses. New-vehicle phase-in of I/M would also reduce the initial fail rate and theoretically keep it low thereafter because of increased mechanic and consumer awareness.

New vehicle phase-in would also inspect those vehicles that are accumulating the higher mileages (kilometrages). From information gathered during in-use testing projects across Canada, vehicles that are four years old or less are responsible for 50% of the total distance travelled by all vehicles. The new vehicle phase-in approach thus is much more effective in improving air quality than that of inspecting only older vehicles as has often been the policy of pioneer I/M programs.

Finally, but of utmost importance to the original goal of improving air quality through I/M, the new vehicle phase-in makes it possible to enforce technically valid (and relatively stringent) emission limits (Chapter 9) almost without reference to politically acceptable failure rates (capture ratios). Moreover, since the initial costs of the program will be borne by the new-vehicle buyer (and manufacturers' warranty programs) the program is politically progressive and will thus have a better public acceptance than programs that put the clean-up costs on the used-car buyer.

7.2 Frequency

The frequency of vehicle inspection is directly related to program effectiveness. There are three basic approaches:

1. random inspection (usually roadside checks);
2. variable frequency inspection (usually on change of owner);
3. fixed inspection (usually annually).

Random inspection offers low-cost operation but normally inspects less than 2% of the vehicle population. The main objective of random inspection is to raise the risk of being caught to a level where maintenance habits are changed. The low inspection rate, however, results in low program impact which in turn severely limits the cost-effectiveness.

The fact that newer vehicles are driven more than older ones makes an I/M program most cost-effective when newer cars are included. Variable frequency inspection on a change of ownership basis would not normally inspect vehicles for the first three years of their life by which time the emissions may have deteriorated beyond redemption. Moreover, the vehicle would have been driven over 40% of its expected lifetime distance. Thus, by the time of its first inspection a large portion of its lifecycle impact will be history.

Fixed frequency inspection on an annual basis is difficult because of the heavy workload required at peak time; this workload then tapers off in non-peak periods. However, many licensing authorities are recognizing that annual registrations in the month of the anniversary of the first registration are less expensive administratively than a single changeover date for the whole fleet.

Vehicle registration in Canada is mostly done on an annual basis and a review of maintenance habits shows that most owners have their vehicles tuned at least once a year. It therefore appears that annual inspection, including an initial inspection at the first registration, would be the most effective I/M frequency.

7.3 Enforcement

A critical component of an I/M program is enforcement. How does one ensure that all of the desired population is inspected and then how can one ensure that failed vehicles are repaired and reinspected?

Most existing I/M programs (18) require proof of inspection at vehicle registration. Some methods involve issuing stickers to passed vehicles and relying on visual police surveillance for actual enforcement. In Switzerland, a staggered mail-out based on date of first registration is used to initiate the inspection process with a feedback system to ensure enforcement.

The optimum method appears to be inspection prior to registration, provided that registration is staggered (based on initial registration) to minimize peak loading. Failing that, the Swiss system seems to be second best.

Some consideration should also be given to not over-penalizing the odd vehicle that cannot be made to pass the standard. The U.S. programs normally have repair cost limits beyond which a failed vehicle will be excused.

7.4 Inspection System Operation

There are essentially two operational options for an I/M program. These are a centralized inspection system (government or contractor operated) and a decentralized inspection system (private certified garages).

The decentralized system would rely entirely on the privately owned garages which would minimize the initial cost to the regulatory agency because of the distribution of test centres. This would also improve consumer convenience but increase the cost per inspection because of the relatively low throughput in each of the numerous test bays.

There could also be a problem of credibility because the garage may be perceived by the customer to have failed the vehicle solely to get the repair business. There is also the problem of developing and maintaining a high level of quality control in these numerous private garages.

A centralized inspection system has the advantage of being unconnected with the repair industry thereby increasing public confidence and credibility. If the system were designed to have one agency for both inspection and enforcement the administration and liaison would be minimized. If it were government operated, budget adjustments for capital expenditures could be difficult and the flexibility would be minimal because of long lead-times, slow hiring practices and the requirement for unusual working hours. Quality control, however, could be more easily handled.

7.5 Implementation Summary

An I/M program can best be implemented by:

1. including new cars and perhaps using a phase-in approach;
2. inspecting vehicles annually, beginning with an initial inspection when the vehicle is first sold and registered and thereafter on the anniversary of the first registration;
3. enforcing the regulations through the registration process and having an upper repair limit beyond which a vehicle is excused;

4. having a contractor operate the inspection program (average inspection cost to consumer is $5 in U.S. programs).

8 I/M TEST PROCEDURE

The primary objective of I/M is to ensure that in-use vehicles are maintained and operated according to the design intent. The test procedure must then determine where individual engines are being operated relative to manufacturers' specifications. Furthermore, it is considered of major importance to have a test procedure that can be easily duplicated in the individual repair facilities.

For I/M purposes, three types of inspection can be considered:

1. loaded mode tests
2. idle mode tests
3. visual inspection.

Within these three there is an unlimited number of further choices. However, for best cost-effectiveness, the loaded test and the visual checks can be eliminated since the dynamometer required to run the loaded test is too expensive for most garages and the visual check alone is ineffective in identifying high emitters.

The idle short test involves a minimum of equipment, can generally identify high emitters, and can easily be conducted in the private repair sector.

In the United States there has been a legislative requirement to correlate any I/M test with the FTP. However, it is uncertain whether the U.S. Congress intended the short test to correlate in the classical statistical sense (19). The requirement for reasonable correlation was to ensure that a short test could identify those vehicles with emissions in excess of the new-vehicle standard with a low error of commission (incorrectly failing a vehicle). However, due to the inherent shortcomings of any short test, such correlation is not possible, but it is possible to identify failing vehicles with a high degree of certainty.

In Canada, there is no requirement for correlation, legislated or otherwise. In fact, as stated earlier, the primary goal of I/M, in the Canadian context, should be to have vehicles running at their optimum condition (manufacturers' specifications) with no reference to passing (or failing) the federally mandated new vehicle emission standards.

8.1 Test Procedure

Only three test procedures appear to merit further examination.

8.1.1 The Hi-Lo Idle Emission Test (Appendix B). The unloaded idle test is presently being used in all existing I/M programs (18). In some cases other tests (such as loaded modes, and 2500 rpm tests) are also being used as preconditioning devices and to provide more detailed diagnostic information.

As it is imperative that an engine be at 'operating' temperature and condition before being subjected to any pass/fail test, preconditioning is in fact necessary. This can be most easily (and cheaply) done by increasing idle speed (in neutral) to 2500 rpm for a period of time while at the same time monitoring the HC and CO readings.

If the engine is cold and/or if the carbon cannister is excessively loaded, the engine will be running somewhat rich (high CO readings) and an extended high idle will serve to warm up the engine and/or purge the cannister. When the CO and HC readings have stabilized at a lower level, they can be recorded. Interpretation of the emission readings at this rpm rate will also provide some diagnostic information.

If it were found that tampering (and/or misfueling) was occurring on a large scale, the emission test could be supplemented by a visual audit of vehicle emission control systems and perhaps some operational checks.

8.1.2 MVMA Recommended Procedure (Appendix C). The MVMA recommended procedure consists of:

1. a visual under-hood inspection of emission-related components for obvious disconnects and tampering;
2. fuel filter inspection to determine misfueling;
3. catalytic converter inspection;
4. EGR functional check;
5. an idle mixture check.

The idle mixture check is conducted by the method specified by the manufacturer.

This method will accomplish the same objectives as the "idle 2500-visual-operational" test mentioned above except in certain situations:

1. if the recommended idle mixture setting is a lean idle drop as opposed to a propane rise or a %CO specification, then adjustments must be made to determine where the mixture is set;
2. if the vehicle has certain mechanical faults (leaking EGR, vacuum leaks, etc.) a propane rpm rise test will not detect the resulting high emissions (if EGR is continuous as the result of a leak, the mixture must be rich to avoid rough idling; if there is a vacuum leak, HC will be high, and to correct, mixture should be richer, etc.);
3. little diagnostic information is available from the propane rise idle mixture method.

Furthermore, there would be a requirement for both propane equipment and exhaust analysis equipment since some manufacturers specify %CO as a recommended idle mixture. Thus, there appears to be no cost or time saving for the I/M operator using this approach.

8.1.3 Mandatory Maintenance. The mandatory maintenance process requires regular (yearly) adjustment, recording and reporting of idle mixture, idle speed, dwell and timing. This could eliminate the requirement for inspection stations but must include extensive monitoring of repair facilities and repaired vehicles. This method may be initially cumbersome to administer because of repair facility certification, and may not be cost-effective. The emphasis is somewhat different in this type of program in that the private garages would not pass or fail vehicles (nor would anyone else) but only adjust vehicles. This could lead to program credibility problems in that the amount of repairs required to get an adjustment certificate would be left to the discretion of the repair facility.

8.2 Recommended Test Procedure

Based on the above discussion, the Hi-Lo idle test procedure (Appendix B) is recommended for I/M programs. This could be supplemented with a visual component check and a functional EGR check for failed vehicles in those areas where tampering is prevalent.

9 EMISSION LIMITS

Emission limits chosen should be such that they put the same relative demands for engine state-of-tune on each individual engine. In all cases, the manufacturers'

specifications are presumably set such that emissions, fuel consumption and performance are optimized for a vehicle in a good state of repair. If each vehicle were tested to meet an emission limit that was related to the design specification, each vehicle would then be tested to the same severity.

This could best be accomplished by having each manufacturer provide CO and HC values at idle and 2500 rpm for a vehicle in a good state of repair and include these values as part of their recommended specifications on an under-hood label. These specifications combined with some kind of age deterioration function would provide equitable and effective emission limits. (It should be noted that the philosophy underlying this procedure for setting in-use emission limits was inspired by the ECE Regulation No. 24 for smoke emissions from diesel engines.)

Since the manufacturers find it difficult to provide CO and HC levels, limits could be set based on engine size and age with the option of using the higher value of either the label value or the set limit. In setting these limits, it is important to consider driveability and fuel consumption.

The following series of equations based on in-use data (section 4) and our new car compliance data meet the objective of setting emission limits:

$$\text{CO (\%) idle emission limit} = 0.5 + \frac{\text{vehicle age (years)}}{10} + 2.0 \text{ (if 4 cyl. or rotary)}$$

OR

$$= \text{label spec.} + \frac{\text{vehicle age (years).}}{10}$$

$$\text{HC (ppm) idle emission limit} = 300 + (30 \times \text{vehicle age (years)})$$

OR

$$= \text{label spec.} + (30 \times \text{vehicle age (years)}).$$

$$\text{CO (\%) 2500 rpm} = 0.3 + \frac{\text{vehicle age (years)}}{10} + 0.5 \text{ (if 4 cyl. or rotary)}$$

OR

$$= \text{label spec.} + \frac{\text{vehicle age (years).}}{10}$$

HC (ppm) 2500 rpm = 200 + (20 x vehicle age (years))

OR

= label spec. + (20 x vehicle age (years)).

A similar approach has been taken for end-of-assembly line inspection in the United States. Each vehicle produced for sale in California (11) must pass a series of functional emission control systems and engine component checks as well as a steady state emission test for hydrocarbons and carbon monoxide to detect any gross malfunction. Manufacturers have control limit values for HC and CO emissions at idle used in their assembly plants for each engine family. For example:

Vehicle	Engine	HC (ppm)	CO (%)
1979 Chrysler	225-1	50	0.3
1979 Ford	4.1 'A'	50	0.35
1979 GM	305	83	0.38
1979 Toyo Kogyo	86.4	60	0.5
1979 Toyota	96.9	50	0.3
1979 Volkswagen	97	50	0.5

It should be noted that these values are for California vehicles, where emission regulations are much more stringent than in Canada, and that they are manufacturing limits, not operational in-use limits.

10 FACTORS AFFECTING THE DECISION TO DEVELOP AND IMPLEMENT AN I/M PROGRAM

In designing an I/M program for a specific area, a number of factors, beyond those already reviewed, should be considered.

10.1 Air Pollution/Fuel Consumption

The requirement to meet the U.S. National Ambient Air Quality Standards in a particular region is the reason behind implementation of I/M in individual states. In the Canadian context, an I/M program may be desirable because of specific air pollution

problems in an urban centre or because of a desire by provincial authorities to reduce fuel consumption, or both.

10.2 Tamperproof Emission Controls

The availability of tamperproof controls on new vehicles, their long-term effectiveness and their penetration into a local vehicle population should be considered in the development of an I/M program.

In the United States, regulations will require that certain engine parameters not be adjustable: idle mixture (1981), choke (1981). The idle mixture control has been introduced on some 1979 and 1980 model cars in Canada and consists of making the access to the mixture screws very difficult. However, some early data from surveys of in-use vehicles indicate that even these controls are being burglarized and carburetors again are being maladjusted rich. While these early samples were small and restricted to two areas (Halifax and Rimouski) they do call into question the effectiveness of this approach. A regulation requiring only a limitation of carburetor adjustment (as opposed to none at all) will be in effect in Canada for the 1982 model year but the current U.S. systems will in all likelihood be carried over to meet the Canadian regulation.

Should these tamperproof systems prove to be effective, the eventual requirement for in-use emission inspection programs would disappear. However, for those areas where specific problems can be solved by I/M, it may be cost-effective to implement a fleet-wide program for a four-to-six-year period, at the end of which time the bulk of distance travelled would be on new-technology vehicles.

10.3 Cost-Benefit Analysis

The costs of setting up and operating a program have been investigated (8) for several existing programs. The typical cost to the motorist is $5 to $8 and this covers all of the capital, administrative and operating costs associated with the program. Thus, there is no net cost to the government. The consumer on average will pay $5 to $10 for repair (carburetor adjustment), drive 30 km to and from inspection and repair locations and receive a minimum benefit (fleet average) of 3% in fuel saving. Assuming the average motorist drives 18 000 km/year, uses 18 L of fuel /100 km at a cost of 30¢/L, his annual fuel costs would be $972. Thus, for a cost of $12 to $20 (including cost to drive to inspection station and repair facility) the average motorist will save a minimum of $29. If the inspection results in higher repair costs, there should be an accompanying increased percentage reduction in fuel consumption.

10.4 I/M Acceptance (20)

Public awareness is an important aspect in developing an effective, acceptable I/M program. Positive advance information should be made available to the public, the politicians and the media before any program is implemented. While it is easy to be negative in the absence of factual information, the availability of facts enhances the likelihood of favourable awareness and thus acceptability.

Appendix A also discusses the public relations aspects of I/M.

10.5 Relevant Existing Programs

In some of the provinces, safety programs have been set up to inspect vehicles annually for safety-related defects. For example, in British Columbia, the provincial government is operating a number of test lanes in the Vancouver area. For minimal costs (capital and administrative) an emission inspection could be included in the existing program. As the program is already government-controlled with a good quality control program and has an existing enforcement system, none of the principles of an effective I/M program would be sacrificed by including an emission inspection. Furthermore in this context, the cost-effectiveness (dollar benefit to the motorist) is higher.

In those provinces where safety programs are conducted at the private garage level, both the credibility and effectiveness of vehicle inspection is greatly compromised for the reasons outlined in section 7.4.

10.6 Departmental Cooperation

In a situation where more than one department will be directly involved with an I/M program (this can include Environment, Transport, Energy, Consumer Affairs, Vehicle Registration), the planning process should include all related groups to ensure a good working relationship.

11 SUMMARY

The goal of an I/M program may vary from province to province or municipality to municipality. In an area where there is concern about air pollution (all U.S. I/M programs) the priorities are different from those in another area where there is concern about excess fuel consumption. Furthermore, the situation in regard to cost-benefit, relevant existing programs and available technology must be evaluated before an I/M

program is implemented. If, as a result of this evaluation, it is determined that I/M is desirable, the program should be designed to:

1. include new cars (perhaps only these vehicles initially, with the remainder being phased in);
2. inspect vehicles on an annual basis beginning with the new car registration and at one-year intervals thereafter;
3. enforce I/M regulations, through the registration system if staggered, or by a mail-out system;
4. be government-controlled and contractor-operated;
5. use a 2500 rpm and idle emission test to determine acceptability (perhaps in conjunction with a visual-functional check if the local tampering rate is high);
6. have emission limits that are fairly stringent and vehicle specific (e.g., CO% at idle = 0.5% for a new 6- or 8-cylinder vehicle).

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APPENDIX A

IMPLEMENTATION OF INSPECTION/MAINTENANCE PROGRAMS

Legal Authority

The first stage in the implementation of an I/M program is the development of appropriate enabling legislation. For the drafting of the enabling legislation, a preliminary description of the major program components should be prepared and the organizational option (centrally located or service station) should be decided upon. Program objectives, operating rules, program dimensions, and major agency responsibilities should be specified. The conduct of the initial planning and trade-off studies should result in the identification of the technical, social, and economic characteristics of the desired I/M program. This aids in the structuring of the legislation.

A considerable period of time can be involved in assuring that such legislation adequately treats all aspects of the desired I/M program. To help expedite matters, EPA has prepared model I/M legislation formats that can greatly assist the states in the development of their own legislation. In addition, other states that currently have legal authority can be used as models. Some of the provisions that should be considered for incorporation in enabling legislation are:

- Adequate authority to adopt rules and regulations concerning
  - requirements for periodic inspection
  - establishment of fees for providing the inspection service
  - withholding vehicle registration for those vehicles that do not satisfactorily complete the inspection or that do not comply with an applicable variance
  - prohibition of tampering;
- Provision for providing adequate funds for implementing, monitoring, and enforcing the I/M program;
- Adequate authority to obtain pertinent data and information, and require periodic reporting of emission information;
- Authority to make emission reports and information available for public inspection;
- Authority to compel compliance with rules and regulations, supported by civil or criminal penalties;
- Provisions for injunctive relief where deemed necessary.

The legislation should also designate the lead agency for the program, most probably the state air pollution control agency, and work out cooperative arrangements with other groups such as the motor vehicle bureau, the department of revenues, the district attorney's office, and other enforcement agencies. State or local consumer protection offices may be included in the program design for surveillance of the service industry. Where the intent is to combine the I/M program with an existing safety inspection program, amendments to existing statutes may be needed.

The product of these efforts is the initial legislation to authorize program development and operation. As the program development advances, it is likely that other issues requiring legislative action will surface. The result will be the revision or modification of the initial legislation. Both Arizona and New Jersey, two states with established inspection programs, have required changes to their original legislation.

The current status of legal authoritiy in areas (U.S.) where I/M is required as part of the transportation control plan is summarized in Appendix Table A-1.

Administrative Factors

In addition to the usual functions of program evaluation and supervision, there are three further areas requiring administrative efforts. There are public relations, consumer protection, and consumer convenience.

Public Relations. The function of a public relations program is to familiarize the public and the repair establishments with an I/M program. This includes the explanation of the purpose and objectives of the program, the program benefits, and the practical workings of the program. Under this latter category, the actual testing procedure should be explained. In addition, information regarding station locations, inspection times, and consumer protection measures should be made available.

A public relations program may take a variety of forms. Advertisements, public service announcements on radio and television, and brochures have all proven to be useful.

Directors of current I/M programs recommend that a public relations program be started six months to a year before any mandatory testing is begun in order to allow vehicle owners to become accustomed to the concept of I/M. In Arizona, such a program was not fully established until after the start of mandatory testing. As a consequence of this, the Arizona I/M program experienced considerable public opposition in its early stages.

TABLE 1 EXTENT OF STATES' CONSIDERATION OF INSPECTION/ MAINTENANCE

State	City	Strategy Requirement SIP	Preliminary Review or Research	Enabling Legislation	I/M Implementation*
Alaska	Fairbanks	X	X		
Arizona	Phoenix	X	X	X	X
	Tucson	X	X	X	X
California	Los Angeles	X	X	X	X
	Sacramento	X	X		
	San Diego	X	X		
	San Francisco	X	X		
	San Joaquin	X	X		
Colorado	Denver	X	X	X	
Connecticut	All		X		
District of Columbia		X	X	X	
Florida	Tampa		X		
Illinois	Chicago	X	X	X	X
Indiana	Indianapolis	X	X		
Kentucky	Covington		X		
	Louisville		X		
Maryland	Baltimore	X	X		
	D.C. Metro Area	X	X		
Massachusetts	Boston	X	X		
	Springfield	X	X		
Minnesota	Twin Cities		X		
Missouri	St. Louis	X	X		
Nevada	Las Vegas	X	X	X	X
	Reno	X	X	X	X
New Jersey	All	X	X	X	X
New York	New York City	X	X		

TABLE 1 EXTENT OF STATES' CONSIDERATION OF INSPECTION/ MAINTENANCE (cont'd)

State	City	Strategy Requirement SIP	Preliminary Review or Research	Enabling Legislation	I/M Implementation*
North Carolina	Charlotte		X		
Ohio	Cincinnati	X	X	X	X
	Dayton		X		
Oregon	Portland	X	X	X	X
Pennsylvania	Philadelphia	X	X	X	
	Pittsburgh	X	X	X	
	Remainder of State		X		
Rhode Island	All	X	X	X	X
Tennessee	Nashville		X		
Texas	Dallas	X	X		
	Houston	X	X		
Utah	Salt Lake City	X	X	X	
Virginia	D.C. Metro Area	X	X		
Washington	Seattle	X	X		
	Spokane	X	X		

* Refer to factsheets in Section 7 for details on the implementation of these programs.

Careful planning of a voluntary maintenance phase before the full mandatory maintenance phase can be very effective in terms of familiarizing the public with goals and procedures of the program. Public opposition can be unintentionally stimulated by having a very high failure rate in the voluntary phase or by having no voluntary phase at all. Voluntary phases have been used in a number of programs, including those in New Jersey, Portland, and Arizona.

Consumer Protection. Provision must be made to ensure that vehicle owners are protected from abuses that could appear in the system (e.g., overcharging by repair

shops and unnecessary repairs) just as care must be taken to avoid hardships in terms of extremely costly repairs or the denial of vehicle registration without due cause. One facet of the consumer protection program is the exemption of certain classes of vehicles, for example, new cars and antique vehicles. In addition, some areas have considered a ceiling on the cost of repairs required for compliance. The ceiling could be either a flat rate or a percentage of the market value of the vehicle. This would eliminate the potential for certain vehicle owners experiencing undue hardships.

Finally, some kind of mechanism should be established to handle consumer complaints concerning overcharging and unnecessary repairs by garages as well as complaints about the program in general. This consumer affairs office could also be responsible for the licensing of repair facilities. If too many complaints about any one repair facility are received, the consumer affairs office could investigate and revoke the licence of the garage if the claims were justified.

Consumer Convenience. An I/M program will be more readily accepted by vehicle owners if their inconvenience in terms of travel and waiting times is minimized. Ideally, the average distance travelled by a vehicle owner to an inspection station is 8 kilometres while a 16-kilometre distance is a reasonable objective as an upper limit. Proximity to local community activity centres is desirable in locating stations.

For a central test lane configuration, providing the option to retest at a private garage can reduce consumer travel and waiting time. A vehicle owner can have his car reinspected at the same facility that performs the repairs and eliminate a second trip to the test station.

The time period between notification of required inspection and the compliance date should be designed to allow ample time for inspection, maintenance and reinspection. It was Arizona's experience that 30 days was not enough time; the legislation has subsequently been revised to permit vehicle inspection during the 90 days prior to registration renewal.

Finally, one of the major concerns of a vehicle owner will be what he will have to pay to have his car inspected. For this reason, and to avoid burdening any population group, the inspection fee should be kept as low as possible.

APPENDIX B

TEST PROCEDURE - HI-LO IDLE

1. Vehicle to be tested should be at operating temperature.
2. Connect tachometer and check calibration of the exhaust emission analyzer (CO-HC).
3. Insert the sample line at least 0.6 m into the tailpipe. When this is not possible, a tailpipe extension should be used. In the case of dual exhaust, either tailpipe can be selected. When exhaust system leaks are obvious, the vehicle should not be tested until repair work is done.
4. Disable the air injection/induction system (as a carburetor is adjusted rich, there is a point on catalyst-equipped vehicles where there is insufficient oxygen to allow the catalyst to function. Injected (or inducted) air extends this point such that it is impossible to identify an over-rich condition with an idle HC-CO test).
5. With transmission in park or neutral, increase engine speed to 2500 rpm for at least 30 seconds until CO and HC readings have stabilized. Record HC and CO.
6. Return engine to free idle. Record stabilized readings of HC, CO and rpm (after at least 10 seconds). If rpm is above 1000 and if this reading is not the recommended idle rpm, the emission readings should be considered invalid.
7. Disconnect test equipment and ensure vehicle air system is reassembled.

APPENDIX C

MVMA INSPECTION/MAINTENANCE PROCEDURE

This procedure emphasizes checking and adjusting to manufacturers' specifications by utilizing manufacturers' service procedures.

1. Visual under-hood inspection for obvious disconnects and tampering

   - Inspect engine for emission-related components that have been removed, tampered with, or disconnected, e.g., belts, hoses, electrical connections. Inspection should not require removal or disconnection of any components.

2. Fuel filler inspection for vehicles requiring use of unleaded fuel

   - Check for presence of unleaded fuel label on instrument panel and at the fuel fill pipe.
   - Remove fuel filler cap.
   - Inspect filler opening and restrictor inside filler neck. Restrictor must be present and must not be damaged.
   - Check restrictor diameter using go-no-go gauge.
   - Install filler cap.

3. Catalytic converter inspection

   - Determine whether vehicle should be equipped with a catalytic converter.
   - Check under vehicle to verify presence of catalytic converter.

4. EGR functional check (all 1973 and later model-year light-duty vehicles)

   - Preferred method

     Connect tachometer (secondary-type preferred) to engine.
     Record engine rpm.
     With engine idling in neutral at normal operating temperature, completely close off the vacuum supply to the EGR valve by pinching the vacuum supply hose with a smooth jaw clamping device, e.g., pair of smooth-jaw pliers.
     Caution - the use of serrated-jaw pliers may rupture vacuum hose.
     Increase engine speed to 2000 rpm (3000 rpm on GM L-4 engines).
     Release clamp.
     On systems that incorporate a vacuum delay, assure sufficient time elapses prior to rpm drop check.

EGR system is functioning properly if engine rpm decreases by 100 when clamp is released.

Return engine to idle and remove tachometer.

- Alternate method (if the EGR valve stem and diaphragm are visible or can be felt by hand by the inspection operator, the following alternate method, although less effective than the preferred method, can be used).

  Modulate the accelerator linkage while watching (or feeling) the EGR valve stem for movement.

  If the EGR valve stem and diaphragm do not move while the engine rpm is varied, the EGR system is not functioning properly.

5. Idle mixture check

- The engine should be at normal operating temperature. Do not test a cold or overheated vehicle.
- Transmission should be in the appropriate gear as designated by the manufacturer (generally Drive for automatics, Neutral for manuals).
- Headlights and accessories should be off.
- The preferred method is that specified by the manufacturer for the particular make and model of vehicle being inspected. To obtain this information, the manufacturer should be contacted.

APPENDIX D

TECHNICAL ADVISORY COMMITTEE (TAC) MEMBERSHIP COMMENTS ON DRAFT REPORT

The members of the TAC were requested to comment on the draft version of this report. These comments (some paraphrased because more than one person made similar comments), along with the appropriate responses, are presented here at the request of the committee. In the majority of cases the responses to the comments are reflected in the report itself.

1. Comment: A list of equipment and man-hour requirements would be useful in doing cost-benefit analysis.
   Response: Cost-benefit analysis is discussed in Section 10.3. Equipment and related costs are discussed in reference 8.

2. Comment: Concerning the emission training of mechanics it appears that a significant number do not know how to tune today's vehicles.
   Response: While mechanic training could be part of the public awareness (Section 10.4) aspect of I/M, new vehicle phase-in (Section 7.1) should allow the problem (if any) to solve itself.

3. Comment: A control option to advise manufacturers and the service industry to "shape-up" in regard to emissions should be discussed.
   Response: This assumes that the service industry and the manufacturers are solely to blame for the problem. It is felt that the problem is a holdover from the early days of emission control and remains as a societal problem (see Introduction). Thus, the fix should be to change the motivation of the consumer to request specific action.

4. Comment: Emission limits should be contingent upon the presence of air injection/induction systems and not engine size.
   Response: As discussed in Appendix B, excess air in the exhaust masks engine operation. Furthermore, statistical analysis has shown age and engine size to be major factors. No reports indicating that emission limits should be a function of air injection/induction have been seen.

5. Comment: The use of the 2500 rpm and idle test poses a problem where identification of failing vehicles is concerned since no exact correlation exists between these tests and the LA No. 4 (FTP) mode test.

Response: Section 8 discusses this.

6. Comment: Emission limits should detect vehicles with unusual conditions only (gross emitters).
   Response: This approach would reduce the capture (fail) rate to about 15% and make the entire program non-cost-effective. Furthermore, many of these gross emitters are older vehicles which travel less than newer vehicles; thus the import of the emission reduction would be minimal.

7. Comment: It is not worthwhile to include new automobiles in an I/M program.
   Response: See Section 7.1.

8. Comment: The I/M system may vary from province to province depending on existing programs and infrastructures.
   Response: See Section 10.5.

9. Comment: One recommended test procedure should be included.
   Response: See Section 8.2.

10. Comment: Emission limits proposed are higher than typical control limits provided by the manufacturer.
    Response: See last paragraph Section 9.

11. Comment: An I/M program affecting current model vehicles would not produce any benefit because of current technology.
    Response: This is true if current technology proves to be effective. See discussion in Section 10.2.

12. Comment: Enforcement programs should be designed to be as convenient as possible for vehicle owners.
    Response: Agreed. Convenience and credibility are major considerations in designing an I/M program.

13. Comment: Repair cost limits should be set to exempt certain vehicles under certain conditions.
    Response: Agreed. See Section 7.3, last paragraph. The repair cost limits should be set such that some penalty is incurred but not to overly burden the economic stability of the individual owner. Normally, $50 to $100 is used.

14. Comment: Failed vehicles should receive a visual inspection of emission-related components and an EGR functional check.

    Response: The information required to do emission component checks complicates and lengthens I/M such that consumer convenience and cost-effectiveness are compromised. As a result it would only be recommended in those areas where emission control tampering is a major concern.

15. Comment: Vehicle-specific emission limits requiring additional labelling would not be cost-effective.

    Response: See Section 9, paragraphs 2 and 3.

16. Comment: Disregard for correlation with the FTP burdens the manufacturer with an additional emission standard.

    Response: This "additional emission standard" does not burden the manufacturer directly but rather the owner. The emission limits are chosen to optimize emissions and fuel consumption without sacrificing driveability and are based on manufacturers' specifications, which presumably can be met.

17. Comment: Steady state tests do not consider the effectiveness of warm-up control systems (choke, preheaters, etc.), transient control units (accelerator pumps, deceleration valves, etc.), EGR operation, full load enrichment or catalyst operation.

    Response: Research has shown that idle mixture is qualitatively and quantitatively the major problem; thus, while the comment is true in absolute terms, there is no reason to check these other parameters. Furthermore, defects in or malfunctions of the warm-up and transient control system would create starting or driveability problems which would motivate the driver to have them repaired.

18. Comment: The idea of centralized government testing stations is acceptable; however, in many of the provinces there would be some interaction with other provincial departments or agencies.

    Response: See Section 10.5 and 10.6.

19. Comment: While there is some correlation between CO at idle and CO in the FTP, there exists no correlation between HC at idle and in the cycle.

    Response: See Section 8, last paragraph.

20. Comment: The HC limit at idle is too low at 240 ppm. It should be 400 ppm.
Response: The 240 ppm HC level at idle and 150 ppm HC at 2500 rpm were based on in-use vehicle and new-vehicle data. The values have been changed to 300 and 200 respectively to allow somewhat more freedom.

21. Comment: The 2500 rpm test does not seem necessary.
Response: A carburetor normally has two circuits - idle and off-idle. The test procedure checks both. The 2500 rpm also preconditions the engine for the idle test.

22. Comment: Is I/M intended for the whole fleet?
Response: I/M is intended to reduce emissions and fuel consumption. Depending on several factors (public acceptance, political constraints, etc.), this can best be accomplished by having the whole fleet inspected. However, it may be desirable to phase in the fleet by model year (newest first) to reduce initial costs, minimize impact (if public acceptance is a problem) and reduce impact on the service industry.

23. Comment: Is any information available with respect to cost-effectiveness?
Response: See Section 10.3.

24. Comment: New emission regulations will negate the need for I/M.
Response: If effective, yes. See Section 10.2.

25. Comment: The report should present typical capital and administrative costs as well as a cost to the motorist.
Response: See Section 10.3 and reference 8.

26. Comment: It is more cost-effecctive to implement I/M in small regions rather than entire provinces.
Response: Agreed. This in fact is recommended.

27. Comment: The benefits of I/M programs should be well publicized to ensure the program is well received.
Response: Agreed. See Section 10.4.

28. Comment: Programs to control in-use motor vehicles should include an inspection of emission control tampering.
Response: See comment 14.

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